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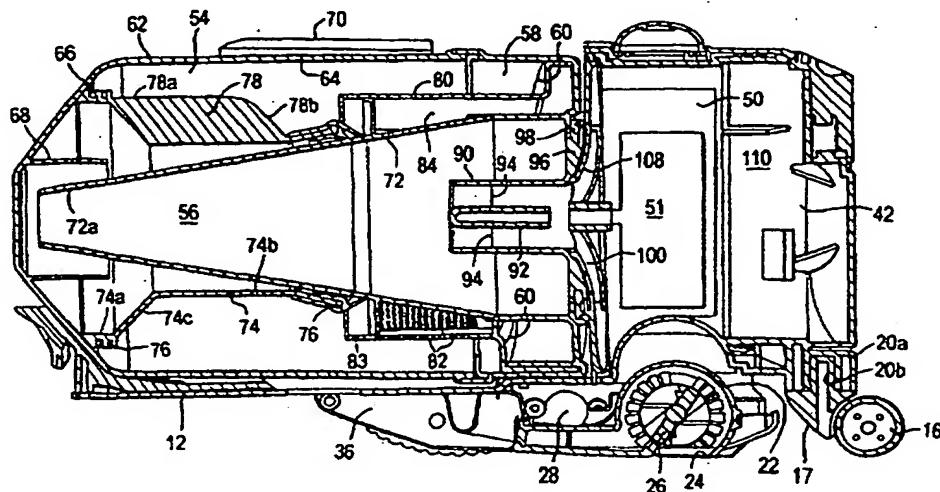
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(54) Abstract Title  
**Cyclonic separator and fan combination**

(57) A cyclonic separator and fan combination is provided in which the cyclonic separator (52) comprises a cyclone body (72), an inlet (86) for introducing fluid to the cyclone body (72) in a helical or swirling manner and an outlet comprising a vortex finder (90) arranged substantially centrally of one end of the cyclone body (72). A fan (100) is arranged immediately downstream of the vortex finder (90) and the fan (100) is adapted to accept and discharge fluid having fine particulates entrained therein. This arrangement allows the dirty fan (100) to operate without the need for any additional swirl-inducing means due to the fact that the vortex finder (90) delivers to the fan (100) a flow of fluid which is already rotating.



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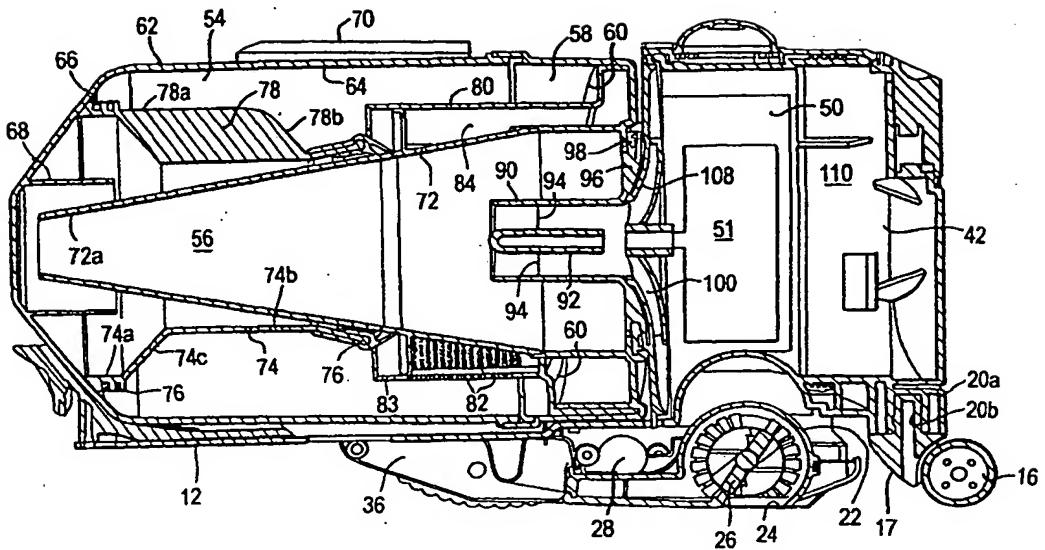
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(54) Title: CYCLONIC SEPARATOR AND FAN COMBINATION



(57) Abstract

A cyclonic separator and fan combination is provided in which the cyclonic separator (52) comprises a cyclone body (72), an inlet (86) for introducing fluid to the cyclone body (72) in a helical or swirling manner and an outlet comprising a vortex finder (90) arranged substantially centrally of one end of the cyclone body (72). A fan (100) is arranged immediately downstream of the vortex finder (90) and the fan (100) is adapted to accept and discharge fluid having fine particulates entrained therein. This arrangement allows the dirty fan (100) to operate without the need for any additional swirl-inducing means due to the fact that the vortex finder (90) delivers to the fan (100) a flow of fluid which is already rotating.

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## Cyclonic Separator and Fan Combination

The invention relates to a cyclonic separator and fan combination, particularly but not exclusively for use in a vacuum cleaner.

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Cyclonic separators are used to separate a comparatively dense material from a comparatively light fluid in which the dense material is entrained. Such separators operate by receiving a flow of fluid and causing the fluid to follow a helical or swirling path so that centrifugal forces are used to separate the comparatively dense material, 10 such as particles, from the comparatively light fluid, such as air. In order for the separator to operate, the flow of fluid has to pass through the separator and the normal manner in which this is achieved is by the creation of a vacuum downstream of the cyclonic separator in order to induce a flow of fluid. When the fluid to be treated is a gas such as air, the vacuum is normally created by using a fan, driven by a motor, 15 positioned downstream of the cyclonic separator.

The output airflow from a cyclonic separator passes through a part called a vortex finder. A pre-motor filter is usually placed downstream of the vortex finder, between the vortex finder and the fan and the motor which drives the fan. The provision of a 20 pre-motor filter is desirable because such a filter eliminates any fine dust particulates from the fluid flow. This then eliminates any risk of deposition of those particulates on the blades of the fan which could prevent the fan from running under optimum conditions. However, it is desirable to remove the pre-motor filter, to make the assembly as compact as possible.

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Fans whose blades are capable of receiving and delivering fluid which has particulates entrained therewithin ("dirty fans") are known and have blades which are essentially radial with little or no arcuate shaping, at least at the upstream ends thereof. The problem which then arises is the fact that axially moving fluid entering the eye of such a 30 fan does not have enough rotational motion to be effectively delivered without a significant pressure drop or other energy loss occurring. This sort of fan generally has

to have a swirl-inducing device located upstream of the fan eye in order to ensure that sufficient rotation is induced before the fluid enters the fan. The swirl-inducing device can take the form of vanes or a tangential offtake placed immediately upstream of the fan. Such devices inevitably require maintenance and add to the cost of the device of  
5 which the fan forms part.

It is therefore an object of the invention to provide a cyclonic separator and fan combination which allows the fan to run dirty but which does not require separate swirl-inducing means in order to allow the fan to run without significant pressure drops or  
10 other losses occurring. It is a still further object of the present invention to provide a cyclonic separator and fan combination in which the fan operates as a dirty fan but whose construction is simple and inexpensive to produce.

Accordingly, an aspect of the invention provides a cyclonic separator and fan  
15 combination in which the cyclonic separator comprises a cyclone body, an inlet for introducing fluid to the cyclone body in a helical or swirling manner and an outlet comprising a vortex finder arranged substantially centrally of one end of the cyclone body, characterised in that the fan is arranged immediately downstream of the vortex finder and the fan is adapted to accept and discharge fluid having fine particulates  
20 entrained therein.

The location of the dirty fan immediately downstream of the vortex finder means that the rotational motion of the fluid exiting the cyclonic separator can be utilised to ensure that the dirty fan operates as if it had a swirl-inducing device immediately upstream  
25 thereof. There is no need to provide additional devices which would require additional maintenance during use and additional cost during manufacture. The arrangement is therefore simple and effective requiring no additional parts or devices to produce a desired result. The positioning of the fan immediately downstream of the vortex finder means that little or no ducting is required to conduct the fluid from the vortex finder to  
30 the fan. This minimises the friction losses associated with ducting in the apparatus of which the cyclonic separator forms part. Preferably, the cyclone body at least is

mounted so as to be separable from the fan and the vortex finder is mounted so as to be irremovable with respect to the fan, the cyclone body at least being mounted so as to be separable from the vortex-finder. This ensures that the eye of the fan is inaccessible by the user, even when the cyclonic separator is emptied, in order to ensure that the fan is  
5 safe to operate.

A particularly simple and effective arrangement is that when the vortex finder is mounted on a structure which is fixed with respect to the fan. This can be a fan casing or a motor casing and the vortex finder can be affixed thereto or integrally moulded  
10 therewith. An advantage of this arrangement is that it eliminates the need for a seal to be positioned at the outlet of the vortex finder. The inclusion of such a seal can introduce a discontinuity in the airflow path and is also vulnerable to deterioration. In any event, the vortex finder is to be irremovable from the fan under normal operating conditions so that the eye of the fan is surrounded at all times by the vortex finder. It is  
15 particularly preferable if the vortex finder contains a centrebody which extends along the longitudinal axis of the vortex finder, but which does not project out therefrom. The centrebody improves the acoustics of the vortex finder. Also, if the centrebody is supported at its distal end by at least one vane member, the or each vane can be helically shaped so that the swirling motion of the fluid traveling along the vortex finder is not  
20 impeded or diminished. The presence of the vane or vanes further impedes any access by the user to the eye of the fan and therefore improves the safety of the operation of the arrangement.

It is also preferred if, in use, the rotational speed of the fan is substantially the same as  
25 the rotational speed of the fluid as it exits the vortex finder. This improves the efficiency of the fan itself.

The arrangement described above is particularly suitable for arrangements in which dirt and dust particles are separated from an airflow and, preferably, for use in vacuum  
30 cleaners. The invention further provides a vacuum cleaner incorporating a cyclonic separator and fan combination as described above.

Further features and advantages of the invention will become apparent from the following description of an embodiment of the invention, which is given by way of example only and is not intended to be limiting, with reference to the accompanying drawings, in which:

- Figure 1 is a perspective view of a vacuum cleaner incorporating a cyclonic separator and fan combination according to the invention;
- Figure 2 is a plan view of the vacuum cleaner of Figure 1;
- Figure 3 is a rear view of the vacuum cleaner of Figure 1;
- 10 Figure 4 is a side view of the vacuum cleaner of Figure 1;
- Figure 5 is an underneath view of the vacuum cleaner of Figure 1;
- Figure 6 is a sectional view taken along the line V-V of Figure 2;
- Figure 7 is a sectional view taken along the line VI-VI of Figure 6 showing only the cleaner head and the cyclonic separator of the vacuum cleaner of Figure 1 and omitting the vortex finder;
- 15 Figure 8 is a perspective view, similar to Figure 1, of the vacuum cleaner but with the cyclonic separator removed and omitting the cleaner head;
- Figure 9 is a front view of the apparatus shown in Figure 8; and
- Figures 10a and 10b are plan and perspective views respectively of the interior of a fan  
20 forming part of the vacuum cleaner of Figure 1.

The vacuum cleaner 10 shown in the drawings has a supporting chassis 12 which is generally circular in shape and is supported on two driven wheels 14 and a castor wheel 16. The chassis 12 is preferably manufactured from high-strength moulded plastics material, such as ABS, but can equally be made from metal such as aluminium or steel. The chassis 12 provides support for the components of the cleaner 10 which will be described below. The driven wheels 14 are arranged at either end of a diameter of the chassis 12, the diameter lying perpendicular to the longitudinal axis 18 of the cleaner 10. Each driven wheel 14 is moulded from a high-strength plastics material and carries a comparatively soft, ridged band around its circumference to enhance the grip of the wheel 14 when the cleaner 10 is traversing a smooth floor. The soft, ridged band also

enhances the ability of the wheels to mount or climb over small obstacles. The driven wheels 14 are mounted independently of one another via support bearings (not shown) and each driven wheel 14 is connected directly to a motor 15 which is capable of driving the respective wheel 14 in either a forward direction or a reverse direction. By 5 driving both wheels 14 forward at the same speed, the cleaner 10 can be driven in a forward direction. By driving both wheels 14 in a reverse direction at the same speed, the cleaner 10 can be driven in a backward direction. By driving the wheels 14 in opposite directions, the cleaner 10 can be made to rotate about its own central axis so as to effect a turning manoeuvre. The aforementioned method of driving a vehicle is well 10 known and will not therefore be described any further here.

The castor wheel 16 is significantly smaller in diameter than the driven wheels 14 as can be seen from, for example, Figure 4. The castor wheel 16 is not driven and merely serves to support the chassis 12 at the rear of the cleaner 10. The location of the castor 15 wheel 16 at the trailing edge of the chassis 12, and the fact that the castor wheel 16 is swivellingly mounted on the chassis by means of a swivel joint 20, allows the castor wheel 16 to trail behind the cleaner 10 in a manner which does not hinder the manoeuvrability of the cleaner 10 whilst it is being driven by way of the driven wheels 14. The swivel joint 20 is most clearly shown in Figure 6. The castor wheel 16 is 20 fixedly attached to an upwardly extending cylindrical member 20a which is received by an annular housing 20b to allow free rotational movement of the cylindrical member 20a therewithin. This type of arrangement is well known. The castor wheel 16 can be made from a moulded plastics material or can be formed from another synthetic material such as Nylon.

25 Mounted on the underside of the chassis 12 is a cleaner head 22 which includes a suction opening 24 facing the surface on which the cleaner 10 is supported. The suction opening 24 is essentially rectangular and extends across the majority of the width of the cleaner head 22. A brush bar 26 is rotatably mounted in the suction opening 24 and a 30 motor 28 is mounted on the cleaner head 22 for driving the brush bar 26 by way of a drive belt (not shown) extending between a shaft of the motor 28 and the brush bar 26.

The cleaner head 22 is mounted on the chassis 12 in such a way that the cleaner head 22 is able to float on the surface to be cleaned. This is achieved in this embodiment in that the cleaner head 22 is pivotally connected to an arm (not shown) which in turn is pivotally connected to the underside of the chassis 12. The double articulation of the connection between the cleaner head 22 and the chassis 12 allows the cleaner head to move freely in a vertical direction with respect to the chassis 12. This enables the cleaner head to climb over small obstacles such as books, magazines, rug edges, etc. Obstacles of up to approximately 25mm in height can be traversed in this way. A flexible connection 30 (see Figure 7) is located between a rear portion of the cleaner head 22 and an inlet port 32 (see also Figure 7) located in the chassis 12. The flexible connection 30 consists of a rolling seal, one end of which is sealingly attached to the upstream mouth of the inlet port 32 and the other end of which is sealingly attached to the cleaner head 22. When the cleaner head 22 moves upwardly with respect to the chassis 12, the rolling seal 30 distorts or crumples to accommodate the upward movement of the cleaner head 22. When the cleaner head 22 moves downwardly with respect to the chassis 12, the rolling seal 30 unfolds or extends into an extended position to accommodate the downward movement.

In order to assist the cleaner head 22 to move vertically upwards when an obstacle is encountered, forwardly projecting ramps 36 are provided at the front edge of the cleaner head 22. In the event that an obstacle is encountered, the obstacle will initially abut against the ramps 36 and the inclination of the ramps will then lift the cleaner head 22 over the obstacle in question so as to avoid the cleaner 10 from becoming lodged against the obstacle. The cleaner head 22 is shown in a lowered position in Figure 6 and in a raised position in Figure 4. The castor wheel 16 also includes a ramped portion 17 which provides additional assistance when the cleaner 10 encounters an obstacle and is required to climb over it. In this way, the castor wheel 16 will not become lodged against the obstacle after the cleaner head 22 has climbed over it.

As can be seen from Figures 2 and 5, the cleaner head 22 is asymmetrically mounted on the chassis 12 so that one side of the cleaner head 22 protrudes beyond the general

circumference of the chassis 12. This allows the cleaner 10 to clean up to the edge of a room on the side of the cleaner 10 on which the cleaner head 22 protrudes.

The chassis 12 carries a plurality of sensors 40 which are designed and arranged to  
5 detect obstacles in the path of the cleaner 10 and its proximity to, for example, a wall or other boundary such as a piece of furniture. The sensors 40 comprise several ultra-sonic sensors and several infra-red sensors. The array illustrated in Figures 1 and 4 is not intended to be limitative and the arrangement of the sensors does not form part of the present invention. Suffice it to say that the vacuum cleaner 10 carries sufficient sensors  
10 and detectors 40 to enable the cleaner 10 to guide itself or to be guided around a predefined area so that the said area can be cleaned. Control software, comprising navigation controls and steering devices, is housed within a housing 42 located beneath a control panel 44 or elsewhere within the cleaner. Battery packs 46 are mounted on the chassis 12 inwardly of the driven wheels 14 to provide power to the motors 15 for  
15 driving the wheels 14 and to the control software. The battery packs 46 are removable to allow them to be transferred to a battery charger (not shown).

The vacuum cleaner 10 also includes a motor and fan unit 50 supported on the chassis 12 for drawing dirty air into the vacuum cleaner 10 via the suction opening 24 in the  
20 cleaner head 22. The motor and fan unit 50 will be described in more detail below. The chassis 12 also carries a cyclonic separator 52 for separating dirt and dust from the air drawn into the cleaner 10. The features of the cyclonic separator 52 are best seen from Figures 6 and 7. The cyclonic separator 52 comprises an outer cyclone 54 and an inner cyclone 56 arranged concentrically therewith, both cyclones 54,56 having their coaxial  
25 axes lying horizontally. The outer cyclone 54 comprises an entry portion 58 which communicates directly with the inlet port 32 as shown in Figure 7. The inlet port 32 and the entry portion 58 together provide an entry into the outer cyclone 54 which is tangential. The direction of the tangential inlet is vertically upward, as shown in Figure 7. It will also be seen from Figure 7 that the inlet, particularly the lower edge 33 thereof, is located so that it is above the lowermost edge or side 35 of the outer cyclone  
30 54. This helps to prevent re-entrainment of dirt and dust into the airflow during

operation. The entry portion 58 is cylindrical and has an end wall 60 which is generally helical. The entry portion 58 opens directly into a cylindrical bin 62 having an outer wall 64 whose diameter is the same as that of the entry portion 58. The cylindrical bin 62 is made from a transparent plastics material to allow a user to view the interior of the outer cyclone 54. The end of the bin 62 remote from the entry portion 58 is frusto-conical in shape and closed. A locating ring 66 is formed integrally with the end of the bin at a distance from the outer wall 64 thereof and a dust ring 68 is also formed integrally with the end of the bin 62 inwardly of the locating ring 66. Located on the outer surface of the bin 62 are two opposed gripper portions 70 which are adapted to assist a user to remove the separator 52 from the chassis 12 for emptying purposes. Specifically, the gripper portions 70 are moulded integrally with the transparent bin 62 and extend upwardly and outwardly from the outer wall 64 so as to form an undercut profile as shown in Figure 1.

15 The inner cyclone 56 is formed by a partially-cylindrical, partially-frusto-conical cyclone body 72 which is rigidly attached to the end face of the entry portion 58. The inner cyclone 56 is open towards the motor and fan unit as will be described below. The cyclone body 72 lies along the longitudinal axis of the transparent bin 62 and extends almost to the end face thereof so that the distal end 72a of the cyclone body 72 is surrounded by the dust ring 68. The gap between the cone opening at the distal end 72a of the cyclone body 72 and the end face of the bin 62 is preferably less than 8mm.

A fine dust collector 74 is located in the bin 62 and is supported by the locating ring 66 at one end thereof. The fine dust collector 74 is supported at the other end thereof by the cyclone body 72. Seals 76 are provided between the fine dust collector 74 and the respective support at either end. The fine dust collector 74 has a first cylindrical portion 74a adapted to be received within the locating ring 66, and a second cylindrical portion 74b having a smaller diameter than the first cylindrical portion 74a. The cylindrical portions 74a, 74b are joined by a frusto-conical portion 74c which is integrally moulded therewith.

A single fin or baffle 78 is moulded integrally with the fine dust collector 74 and extends radially outwardly from the second cylindrical portion 74b and from the frusto-conical portion 74c (see Figure 6). The outer edge 78a of the fin 78 is aligned with the first cylindrical portion 74a and also with the wall of the shroud 80. The inclined edge 5 78b of the fin 78 remote from the first cylindrical portion 74a lies essentially parallel to the frusto-conical portion 74c. The outer and inclined edges 78a, 78b are joined by a smooth curve moulded into the fin 78.

The single fin 78 extends upwardly from the fine dust collector 74. The angle at which 10 the fin extends can be varied within certain limits and it is not intended that the fin may only extend upwardly at 90° to a horizontal plane. However, the capacity of the bin 62 is put to the best use if the fin 78 does extend from the fine dust collector generally upwardly towards the wall of the bin 62. The radial extent of the fin 78 may also vary. In the illustrated embodiment, the fin 78 extends approximately one half of the distance 15 between the fine dust collector and the bin 62, although it is envisaged that this distance could be varied between one quarter and one half of the said distance.

A shroud 80 is located between the first and second cyclones 54, 56. The shroud 80 is cylindrical in shape and is supported at one end by the entry portion 58 and by the 20 cyclone body 72 of the inner cyclone 56 at the other end. As is known, the shroud 80 has perforations 82 extending therethrough and a lip 83 projecting from the end of the shroud 80 remote from the entry portion 58. A channel 84 is formed between the shroud 80 and the outer surface of the cyclone body 72, which channel 84 communicates with an entry port 86 leading to the interior of the inner cyclone 56 in a manner which forces the incoming airflow to adopt a swirling, helical path. This is 25 achieved by means of a tangential or scroll entry into the inner cyclone 56 as can be seen from Figure 7

A vortex finder 90 is located centrally of the larger end of the inner cyclone 56 to 30 conduct air out of the cyclonic separator 52 after separation has taken place. The vortex finder 90 has a centrebody 92 located therein to reduce the noise of the swirling exiting

air. The centrebody 92 lies along the axis of the vortex finder 90 but does not project beyond the distal end thereof. The centrebody 92 is supported at its distal end by a pair of diametrically opposed vanes 94 which extend between the centrebody 92 and the interior wall of the vortex finder 90. The vanes 94 are helically shaped so that, as swirling air passes along the vortex finder 90, the rotational motion of the air is not diminished by the presence of the vanes 94. The centrebody 92 is integrally moulded with the vanes 94 and mouldings (not shown) are provided to allow the centrebody 92 to be snap-fitted into position within the vortex finder 90. It is envisaged that the centrebody 92 and the vanes 94 could be integrally moulded with the vortex finder 90 if desired.

The vortex finder 90 is moulded integrally with a casing part 96 which is generally shaped like an annular plate and forms part of the casing for the fan and motor unit 50. An annular lip seal 98 is secured to the casing part 96 at a location such that it cooperates with the open end of the inner cyclone 56. It is preferable to locate the annular seal 98 in an upstream part of the cyclonic separator 52 because the underpressure is low in comparison to downstream parts and the seal is therefore less prone to wear and damage. The location of the cyclonic separator 52 on the chassis 12 brings the open end of the inner cyclone 56 into abutting engagement with the annular seal 98 thereby closing the inner cyclone 56 by means of the casing part 96. The vortex finder 90 projects into the interior of the inner cyclone 56 to form the only outlet therefrom.

A fan 100 is arranged immediately downstream of the vortex finder 90. Indeed, the fan 100 is located so that the vortex finder 90 opens directly into the eye of the fan 100. The interior of the fan is shown in more detail in Figures 10a and 10b. As can be seen from the drawings, the blades 102 of the fan 100 extend radially outwardly from the hub 104 towards the periphery 106, at least at their innermost ends. Each blade 102 thus has a relatively straight inner portion 102a and an arcuate outer portion 102b. The relatively straight portion 102a ensures that the fan 100 is able to "run dirty", ie, to operate so as to deliver air with particulates entrained therein without the particulates becoming

- lodged on the blades. The fan is manufactured from a plastics material such as polyester or glass-filled polyester and energy directors are moulded into the upper surfaces of the blades so that a cover 108 can be ultrasonically welded to the fan part shown in Figures 10a and 10b. The cover has an aperture whose diameter corresponds exactly to that of the vortex finder 90 so that all of the air exiting the vortex finder 90 enters the eye of the fan 100. The fan 100 is also mounted directly on the motor 51 and is driven thereby at a speed of somewhere in the region of 30,000rpm. The motor 51 is suspended within the motor and fan unit 50 in a known manner so that any vibrations are absorbed. The air exiting the fan 100 is allowed to flow past the motor 51 providing a cooling effect before being conducted into a post-motor filter housing 110. A post-motor filter (not shown) is normally housed within the post-motor filter housing 110 and the air exiting the motor and fan unit 50 passes through the filter in order to ensure that there are virtually no particulates emitted into the atmosphere, including carbon particulates which may be released within the motor 51. The air emitted from the vacuum cleaner 10 may also be passed through the battery packs 46 in order to provide a cooling effect before being expelled to the atmosphere via vents 46a in the forward surfaces of the battery packs 46. It will be noted that there is no possibility of providing a pre-motor filter in the arrangement just described.
- 20 The entire cyclonic separator 52 is releasable from the chassis 12 in order to allow emptying of the outer and inner cyclones 54, 56. A hooked catch (not shown) is provided adjacent the inlet port 32 by means of which the cyclonic separator 52 is held in position when the cleaner 10 is in use. When the hooked catch is released (by manual pressing of a button 34 located in the control panel 44), the cyclonic separator 25 52 can be lifted away from the chassis 12 by means of the gripper portions 70. The bin 62 can then be released from the entry portion 58 (which carries with it the shroud 80 and the inner cyclone body 72) to facilitate the emptying thereof. When the cyclonic separator 52 is released from the chassis 12 in this way, the vortex finder 90 remains irremovably fixed in position with respect to the fan 100. The end portion 58, the bin 30 62, the inner cyclone 52, the shroud 80 and the fine dust collector 74 are all separable from the fan 100 and the vortex finder 90 in order to effect emptying of the bin 62 and

the fine dust collector 74. However, the vortex finder 90 remains affixed to the casing part 96 which remains irremovably fixed with respect to the fan and continues to shield it. The vortex finder 90 itself prevents a user's fingers from entering the eye of the fan and protects the fan 100 in that respect. The presence of the centrebody 92 and the vanes 94 add to the protection afforded by the vortex finder assembly.

The vacuum cleaner 10 described above operates in the following manner. In order for the cleaner 10 to traverse the area to be cleaned, the wheels 14 are driven by the motors 15 which, in turn, are powered by the batteries 46. The direction of movement of the cleaner 10 is determined by the control software which communicates with the sensors 40 which are designed to detect any obstacles in the path of the cleaner 10 so as to navigate the cleaner 10 around the area to be cleaned. Methodologies and control systems for navigating a robotic vacuum cleaner around a room or other area are well documented elsewhere and do not form part of the inventive concept of this invention. Any of the known methodologies or systems could be implemented here to provide a suitable navigation system.

The batteries 46 also provide power to operate the motor and fan unit 50 to draw air into the cleaner 10 via the suction opening 24 in the cleaner head 22. The motor 28 is also driven by the batteries 46 so that the brush bar 26 is rotated in order to achieve good pick-up, particularly when the cleaner 10 is to be used to clean a carpet. The dirty air is drawn into the cleaner head 22 and conducted to the cyclonic separator 52 via the telescopic conduit 30 and the inlet port 32. The dirty air then enters the entry portion 58 in a tangential manner and adopts a helical path by virtue of the shape of the helical wall 60. The air then spirals down the interior of the outer wall 64 of the bin 62 during which motion any relatively large dirt and fluff particles are separated from the airflow. The separated dirt and fluff particles collect in the end of the bin 62 remote from the entry portion 58.

The fin 78 discourages uneven accumulation of dirt and fluff particles and helps to distribute the dirt and fluff collected around the end of the bin 62 in a relatively even

manner. It achieves this by providing a baffle against which dirt and dust separated in the outer cyclone 54 can accumulate. The constant airflow within the bin 62 presses the separated dirt and dust against the fin or baffle 78 and a build-up of dirt and dust occurs. The location of the fin or baffle 78 at an uppermost point within the bin 62 means that the initial build-up of dirt and dust is located in that area. As the build-up of dirt and dust continues, the accumulated dirt and dust forms builds up around the inner wall of the bin 62 and the accumulation is relatively even and uniform. The provision of the fin or baffle 78 parallel to the direction of the tangential inlet port 32 maximises the amount of separated dirt and dust which can be accommodated in the bin 62.

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The airflow from which dirt and larger fluff particles has been separated moves inwardly away from the outer wall 64 of the bin 62 and travels back along the exterior wall of the fine dust collector 74 towards the shroud 80. The presence of the shroud 80 also helps to prevent larger particles and fluff traveling from the outer cyclone 54 into the inner cyclone 56, as is known. The air from which comparatively large particles and dirt has been separated then passes through the shroud 80 and travels along the channel between the shroud 80 and the outer surface of the inner cyclone body 72 until it reaches the inlet port 86 to the inner cyclone 56. The air then enters the inner cyclone 56 in a helical manner and follows a spiral path around the inner surface of the cyclone body 72. Because of the frusto-conical shape of the cyclone body 72, the speed of the airflow increases to very high values at which the fine dirt and dust still entrained within the airflow is separated therefrom. The fine dirt and dust separated in the inner cyclone 56 is collected in the fine dust collector 74 outwardly of the dust ring 68. The dust ring 68 discourages re-entrainment of the separated dirt and dust back into the airflow.

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When the fine dirt and dust has been separated from the airflow, the cleaned air exits the cyclonic separator via the vortex finder 90. The spinning air then enters the fan 100 directly from the vortex finder. The rotational movement of the air means that the "dirty" fan 100 is still able to operate without a significant pressure drop or similar losses and without there being any risk of detrimental build-up of particulates which may remain entrained within the air flow. The air is passed over or around the motor 51

in order to cool the motor 51 before it is expelled into the atmosphere via the post-motor filter housing 110 and, if required, via the battery housings 46.

The invention is not intended to be limited to the precise details of the embodiment described above. Indeed, the invention is applicable to many different types of cyclonic separator and fan combinations, not only in the context of a vacuum cleaner. This is only one application of many. What is essential to the invention is the provision of a cyclonic separator and an associated fan for producing a flow of fluid through the separator, the fan being positioned immediately downstream of the vortex finder of the cyclonic separator. It is to be understood that, when the vortex finder is stated as being irremovable with respect to the fan, the ability to remove the vortex finder or fan from the other respective part for occasional access is to be permitted. For example, it might be desirable to allow access to the fan for maintenance purposes via the vortex finder. These acts, which would be carried out only very occasionally (perhaps once in twelve months), do not interfere with the general concept of the vortex finder remaining irremovable with respect to the fan during normal operation of the cyclonic separator and the emptying of the collection chamber or bin thereof. The nature of the fluid to be treated by the separator is not to be regarded as limited to air, or indeed to a gas. Other fluids can be treated by means of the separator according to the invention. In the context of a vacuum cleaner, the invention is not to be regarded as applicable only to a robotic or autonomous cleaner; it is applicable to other types of cleaner as well. For example, conventional upright, cylinder or back-pack cleaners may also advantageously incorporate a combination according to the invention. If a combination according to the invention is incorporated into an autonomous vacuum cleaner, it will be understood that the means by which the cleaner is able to navigate or be driven across a surface to be cleaned is not material to the invention and any appropriate means of achieving these functions can be used to achieve the same effect.

**Claims:**

1. A cyclonic separator and fan combination in which the cyclonic separator comprises a cyclone body, an inlet for introducing fluid to the cyclone body in a helical or swirling manner and an outlet comprising a vortex finder arranged substantially centrally of one end of the cyclone body, characterised in that the fan is arranged immediately downstream of the vortex finder and the fan is adapted to accept and discharge fluid having fine particulates entrained therein.
- 10 2. A cyclonic separator and fan combination as claimed in claim 1, wherein the cyclone body at least is mounted so as to be separable from the fan and the vortex finder is mounted so as to be irremovable with respect to the fan, the cyclone body at least being mounted so as to be separable from the vortex finder.
- 15 3. A cyclonic separator and fan combination as claimed in claim 1 or 2, wherein the fan has a plurality of blades which extend substantially radially, at least at their upstream ends.
- 20 4. A cyclonic separator and fan combination as claimed in claim 1 or 3, wherein the vortex finder is mounted on a structure which is fixed with respect to the fan.
5. A cyclonic separator and fan combination as claimed in claim 4, wherein the fan is enclosed by a casing and the vortex finder is mounted on the said casing.
- 25 6. A cyclonic separator and fan combination as claimed in claim 5, wherein the vortex finder is integrally moulded with the casing.
7. A cyclonic separator and fan combination as claimed in claim 4, wherein the fan is surrounded by a motor casing and the vortex finder is mounted on the motor casing.

8. A cyclonic separator and fan combination as claimed in any one of the preceding claims, wherein a centrebody is mounted within the vortex finder.

9. A cyclonic separator and fan combination as claimed in claim 8, wherein the centrebody does not project beyond the distal end of the vortex finder.

10. A cyclonic separator and fan combination as claimed in claim 8 or 9, wherein the distal end of the centrebody is braced or supported by at least one vane member extending between the vortex finder and the centrebody.

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11. A cyclonic separator and fan combination as claimed in claim 10, wherein the or each vane member is helically shaped so that, in use, the swirling motion of a fluid traveling along the vortex finder is not diminished by the presence of the vane or vanes.

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12. A cyclonic separator and fan combination as claimed in any one of the preceding claims, wherein the fan is mounted directly on an output shaft of a motor which, in use, drives the fan.

20

13. A cyclonic separator and fan combination as claimed in any one of the preceding claims, wherein, in use, the fan is driven at a rotational speed substantially the same as that of the fluid exiting the cyclonic separator.

25

14. A cyclonic separator and fan combination as claimed in any one of the preceding claims, wherein the cyclonic separator comprises an upstream cyclone and a downstream cyclone arranged in series.

15. A cyclonic separator and fan combination as claimed in claim 14, wherein the cyclone body forms part of the downstream cyclone.

16. A cyclonic separator and fan combination as claimed in claim 14 or 15, wherein the upstream cyclone comprises a generally cylindrical outer bin and the cyclone body is arranged inside the said bin.
- 5 17. A cyclonic separator and fan combination as claimed in any one of the preceding claims, wherein the cyclone body is frusto-conical in shape.
- 10 18. A cyclonic separator and fan combination as claimed in any one of the preceding claims, wherein the cyclonic separator is adapted to separate dirt and dust from an airflow.
19. A cyclonic separator and fan combination as claimed in claim 18, wherein the combination forms part of a vacuum cleaner.
- 15 20. A cyclonic separator and fan combination as claimed in claim 19, wherein the vacuum cleaner is autonomous.
21. A vacuum cleaner incorporating a cyclonic separator and fan combination as claimed in any one of the preceding claims.

1/10

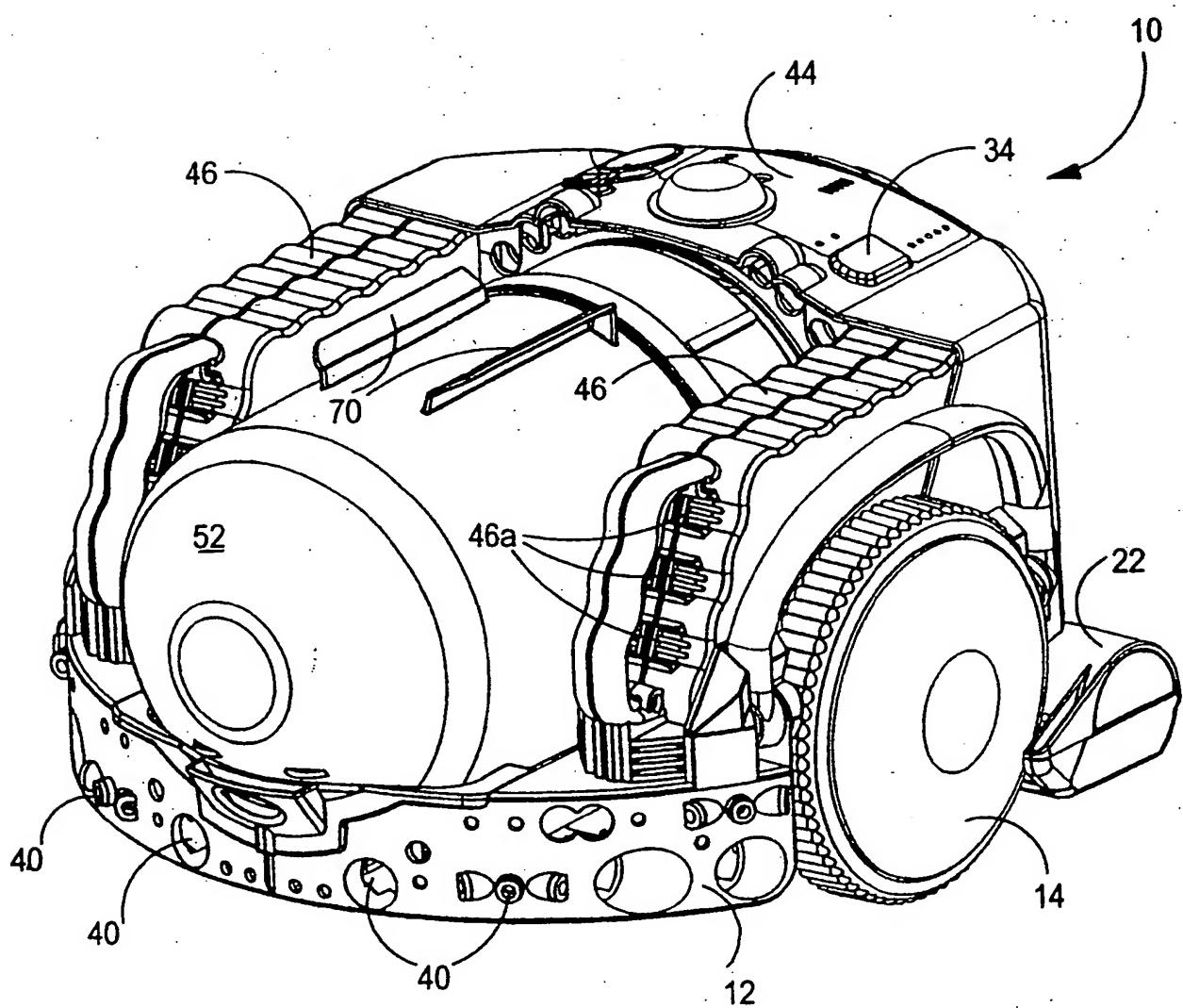


FIG.1.

2/10

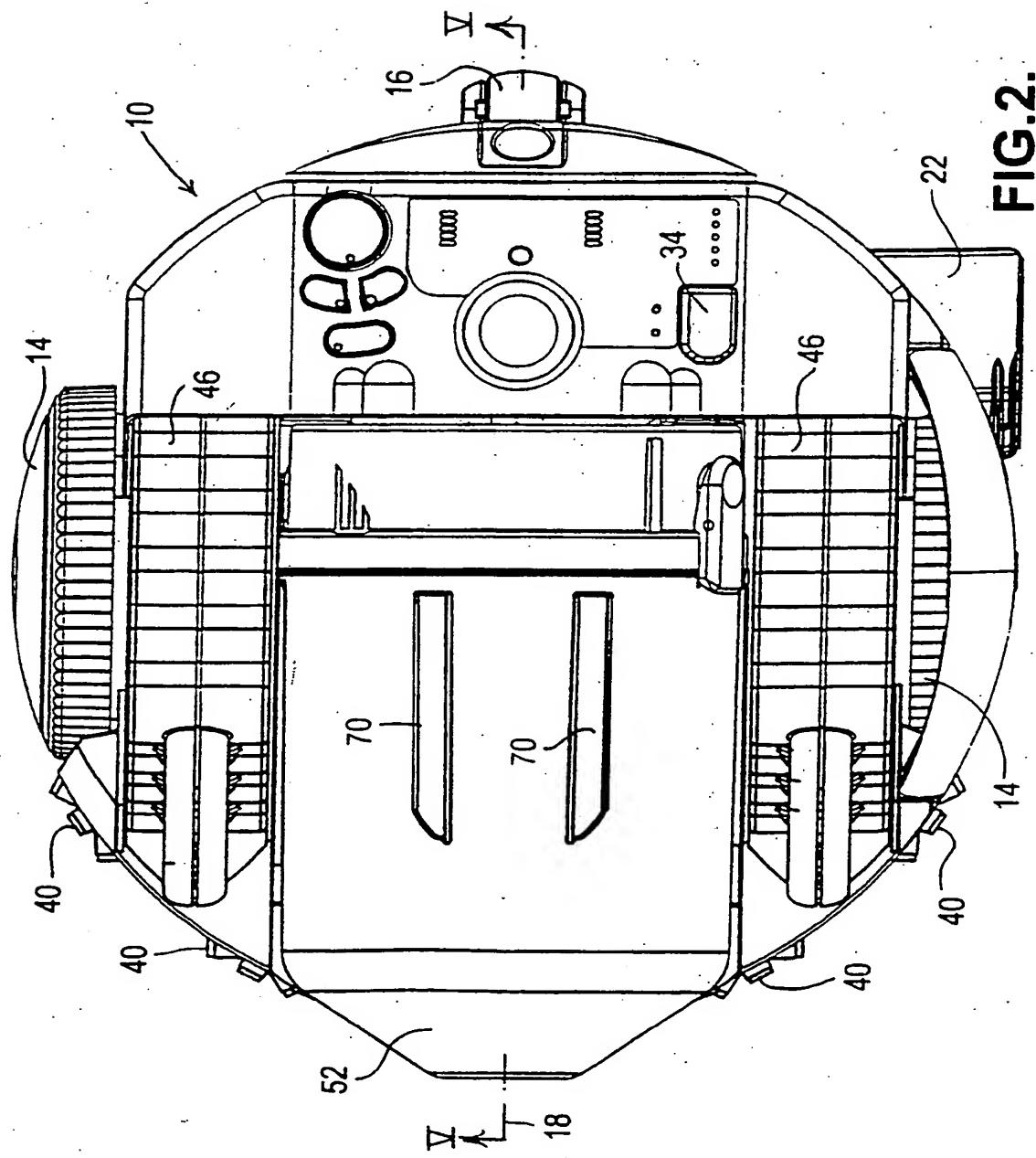


FIG.2.

3/10

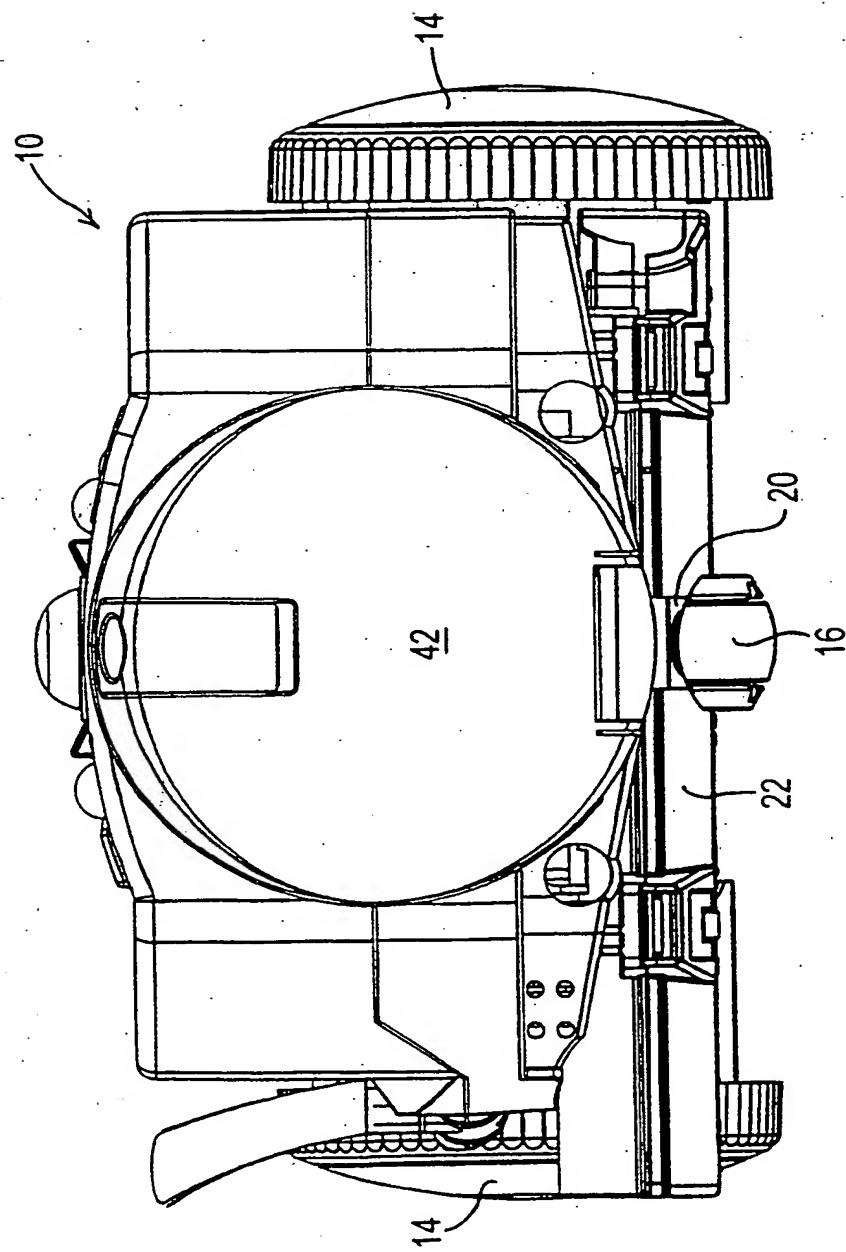


FIG.3.

4/10

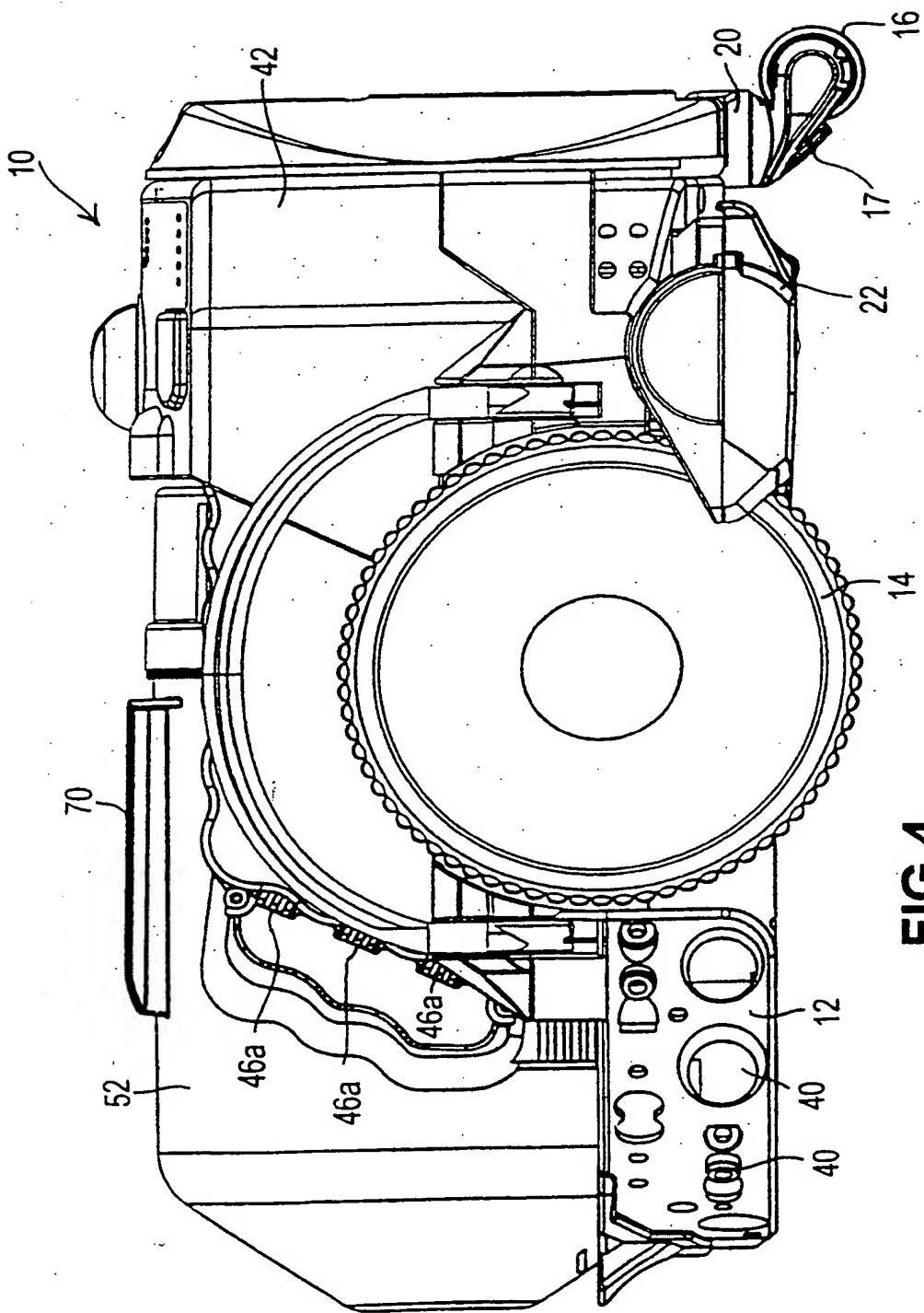
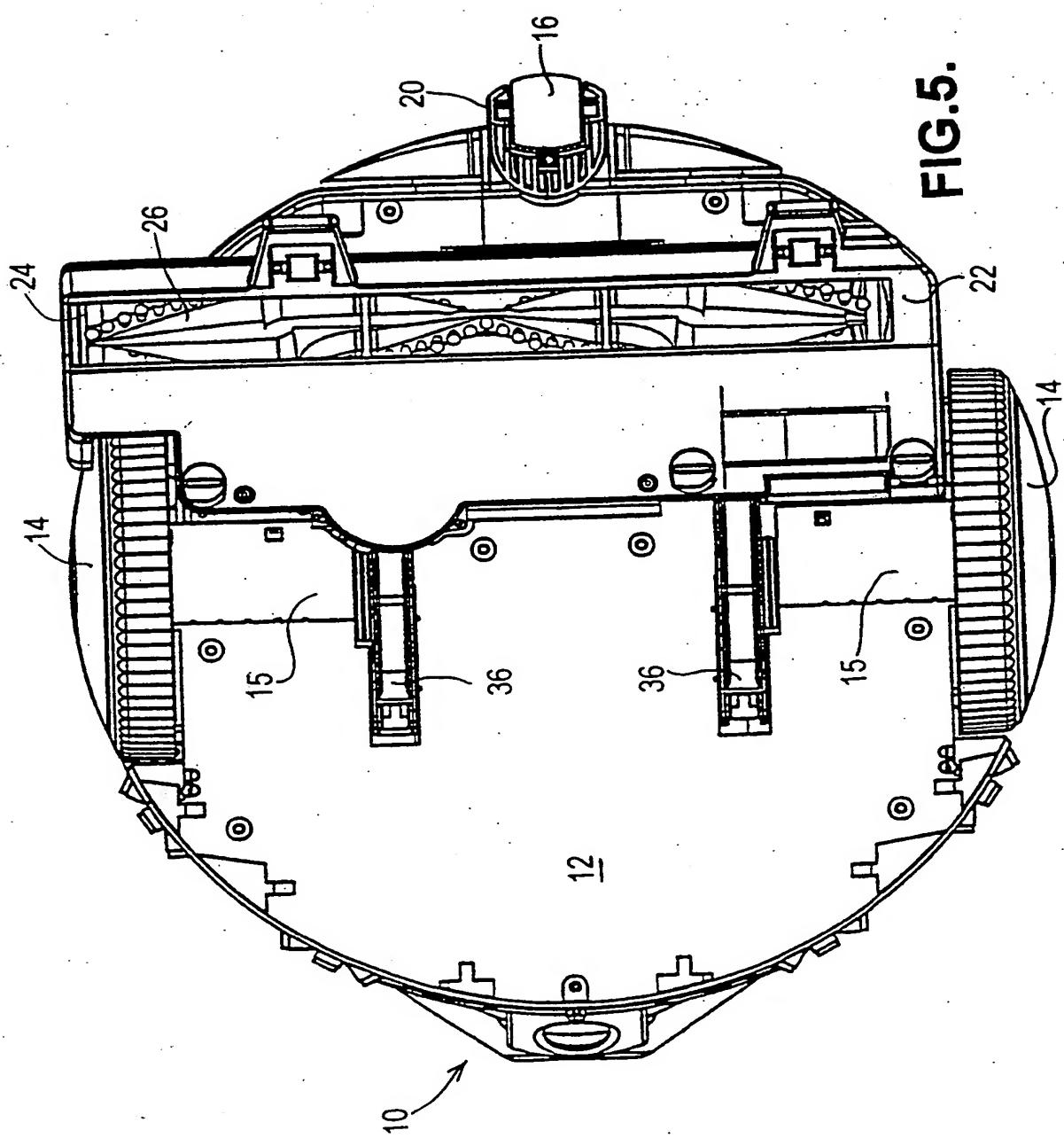


FIG.4.

5/10



6/10

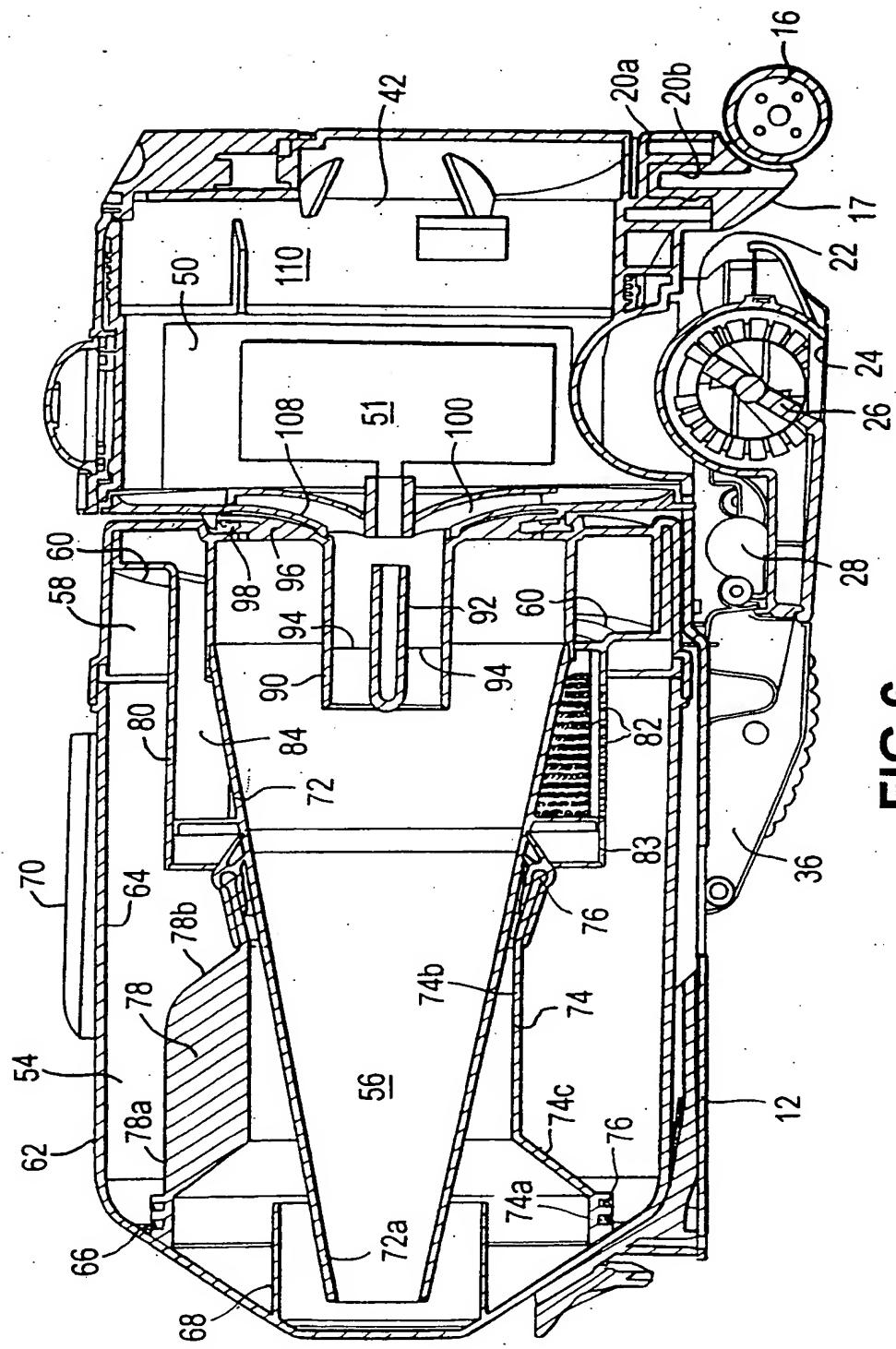


FIG. 6.

7/10

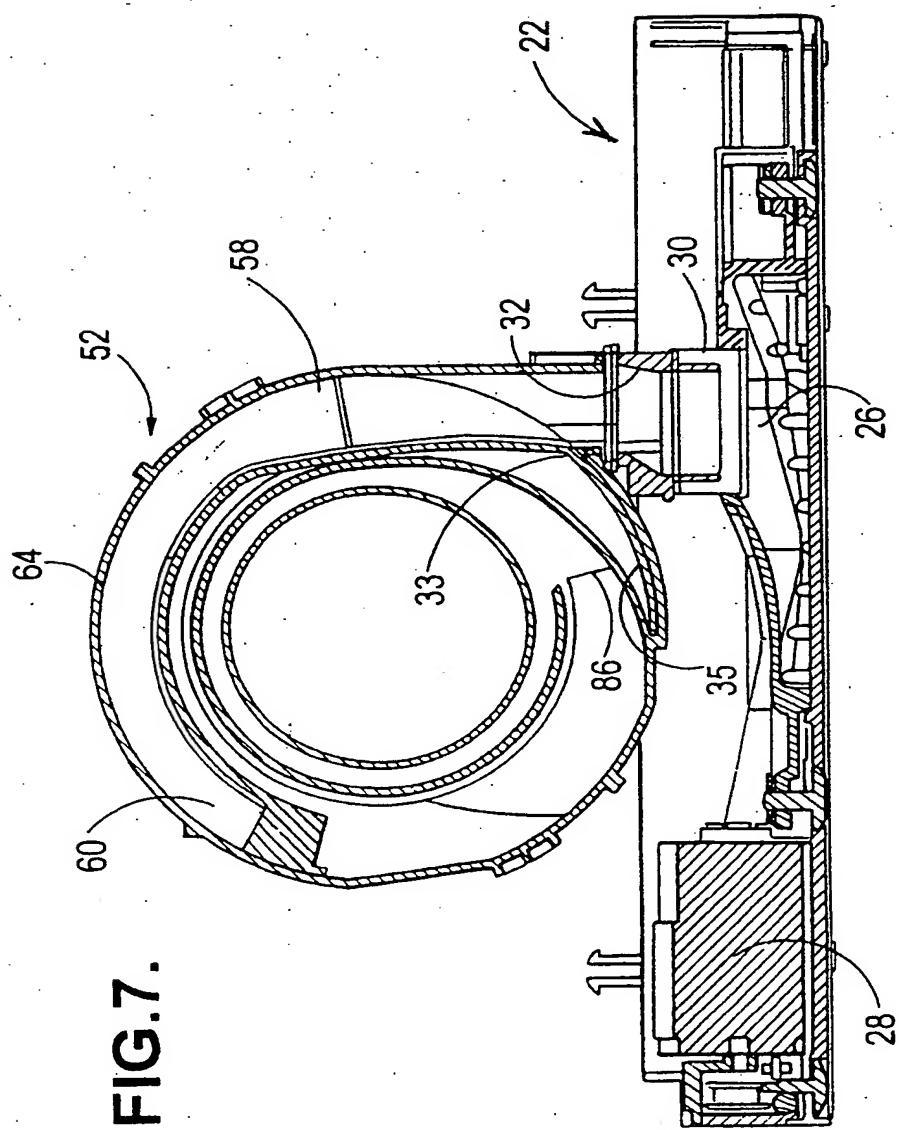
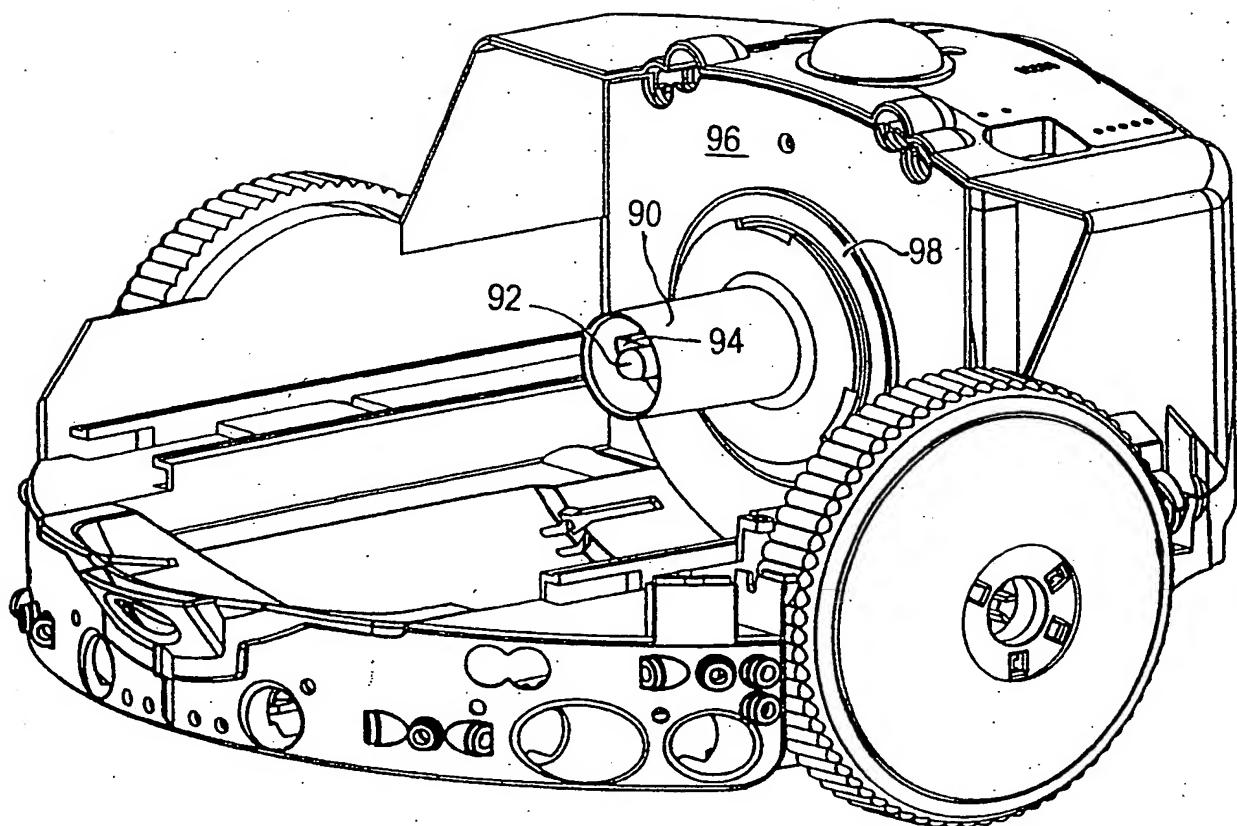


FIG. 7.

8/10



**FIG.8.**

9/10

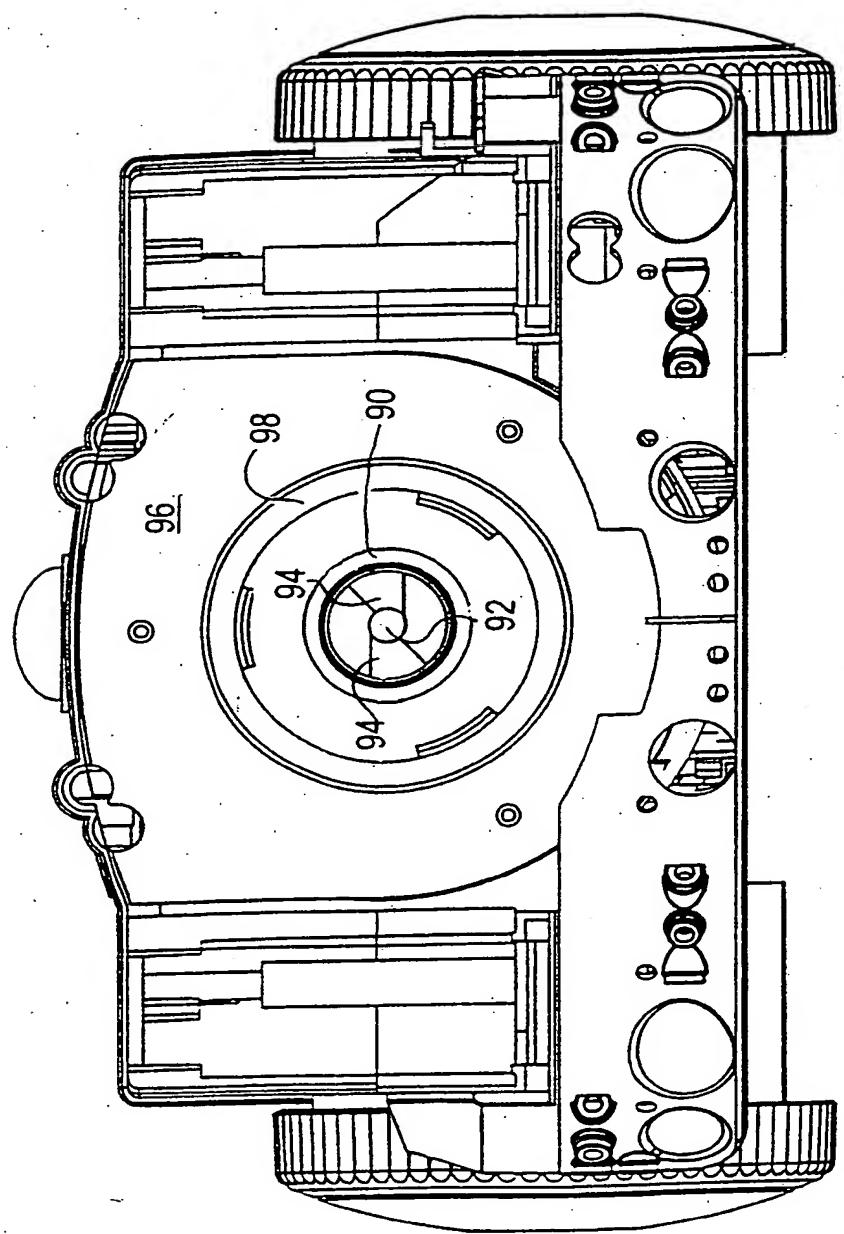


FIG.9.

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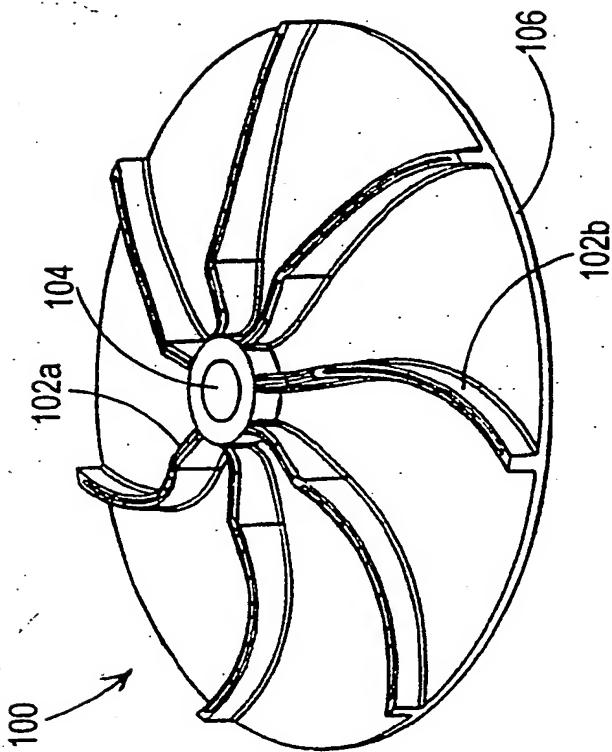


FIG. 10b.

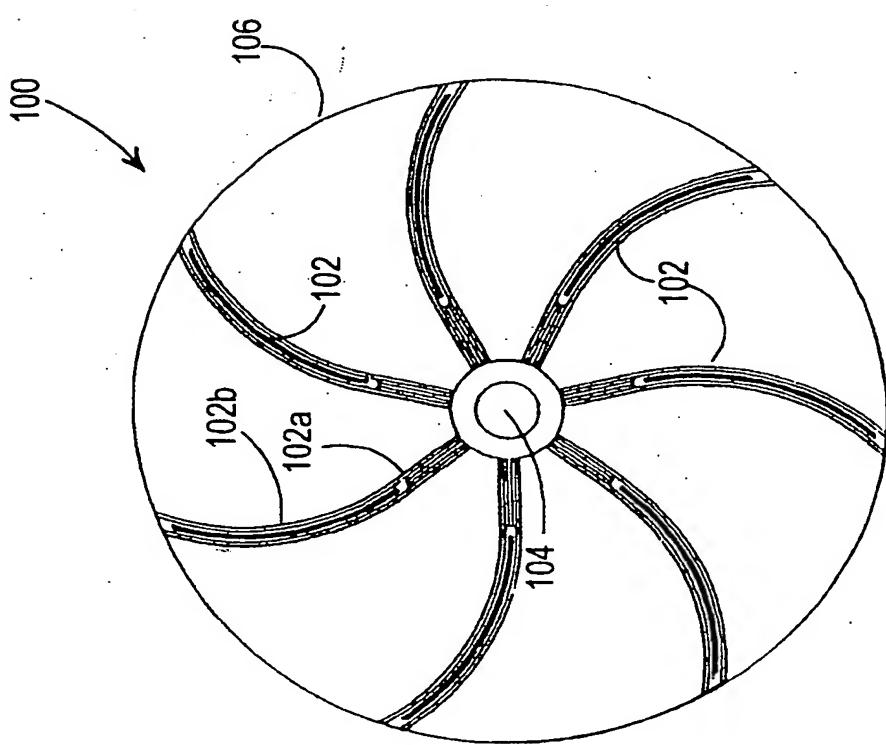


FIG. 10a.

# INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 99/04069

**A. CLASSIFICATION OF SUBJECT MATTER**  
 IPC 7 A47L9/16 / B04C5/13 A47L9/22

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
 IPC 7 A47L B04C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 728 435 A (BLACK & DECKER INC) 28 August 1996 (1996-08-28) column 2, line 48 -column 3, line 10 figures 1,3	1,4,12, 14-19,21
Y	---	3,8-11, 20
X	EP 0 557 096 A (IONA APPLIANCES INC) 25 August 1993 (1993-08-25) abstract column 6, line 36 -column 7, line 53 figures 3,4,6 ---	1,4,12, 14-19,21

Further documents are listed in the continuation of box C.

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Date of the actual completion of the international search

20 March 2000

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## INTERNATIONAL SEARCH REPORT

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## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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